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**Hung et al.**

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(54) **METHOD FOR FABRICATING A TRANSFORMER INTEGRATED WITH A SEMICONDUCTOR STRUCTURE**

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(52) **U.S. Cl.** ..... **29/605**; 29/602.1; 29/606; 310/179; 310/201; 310/207; 310/208; 336/176; 336/200; 336/229

(58) **Field of Classification Search** ..... 29/602.1, 29/605, 606; 310/68 R, 179, 201, 207, 208; 336/176, 200, 229

See application file for complete search history.

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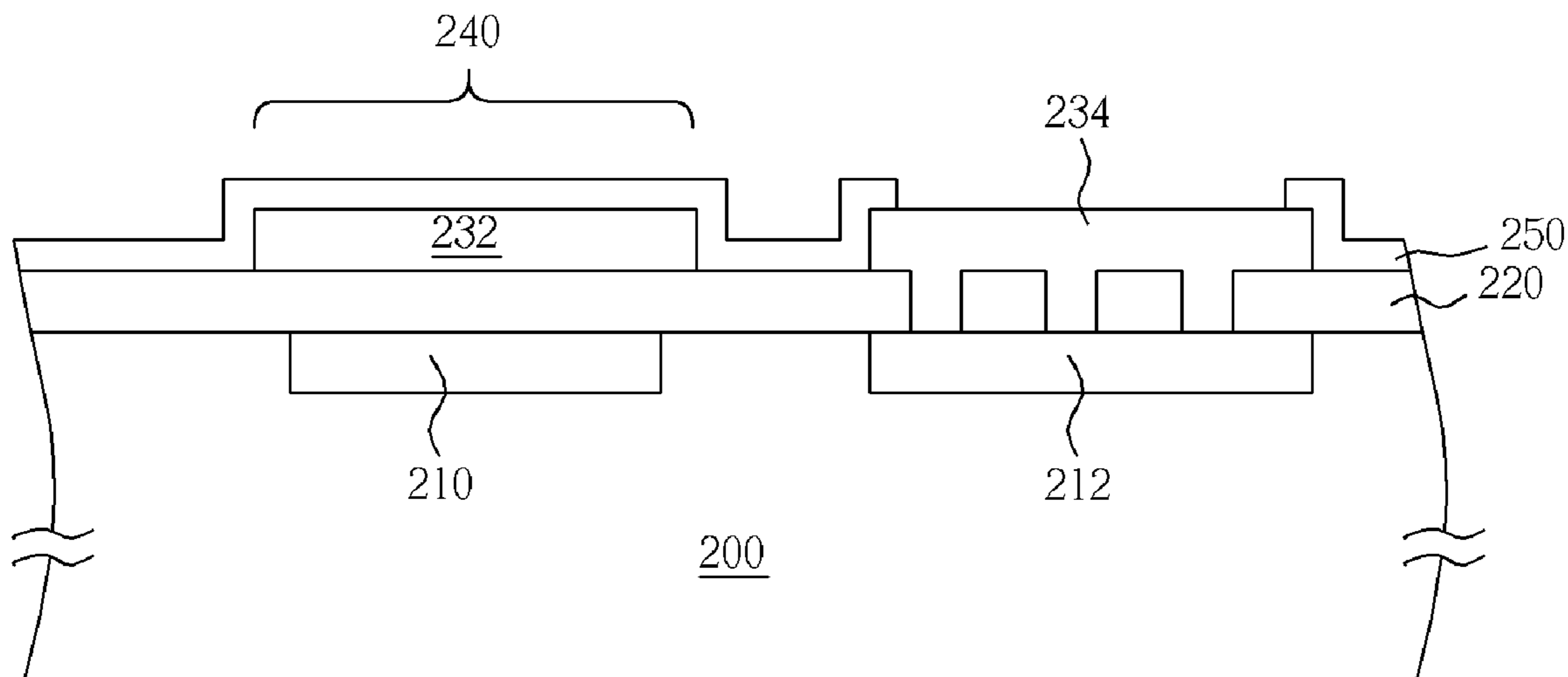
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(57) **ABSTRACT**

A substrate is provided and a top interconnection metal layer and a primary winding layer are formed thereon. Then a passivation layer having a plurality of via exposed parts of the top interconnection metal layer is formed on the substrate. A secondary winding layer and at least a bonding pad are formed on the passivation layer. The bonding pad electrically connects to the top interconnection metal layer through the via.

**10 Claims, 11 Drawing Sheets**



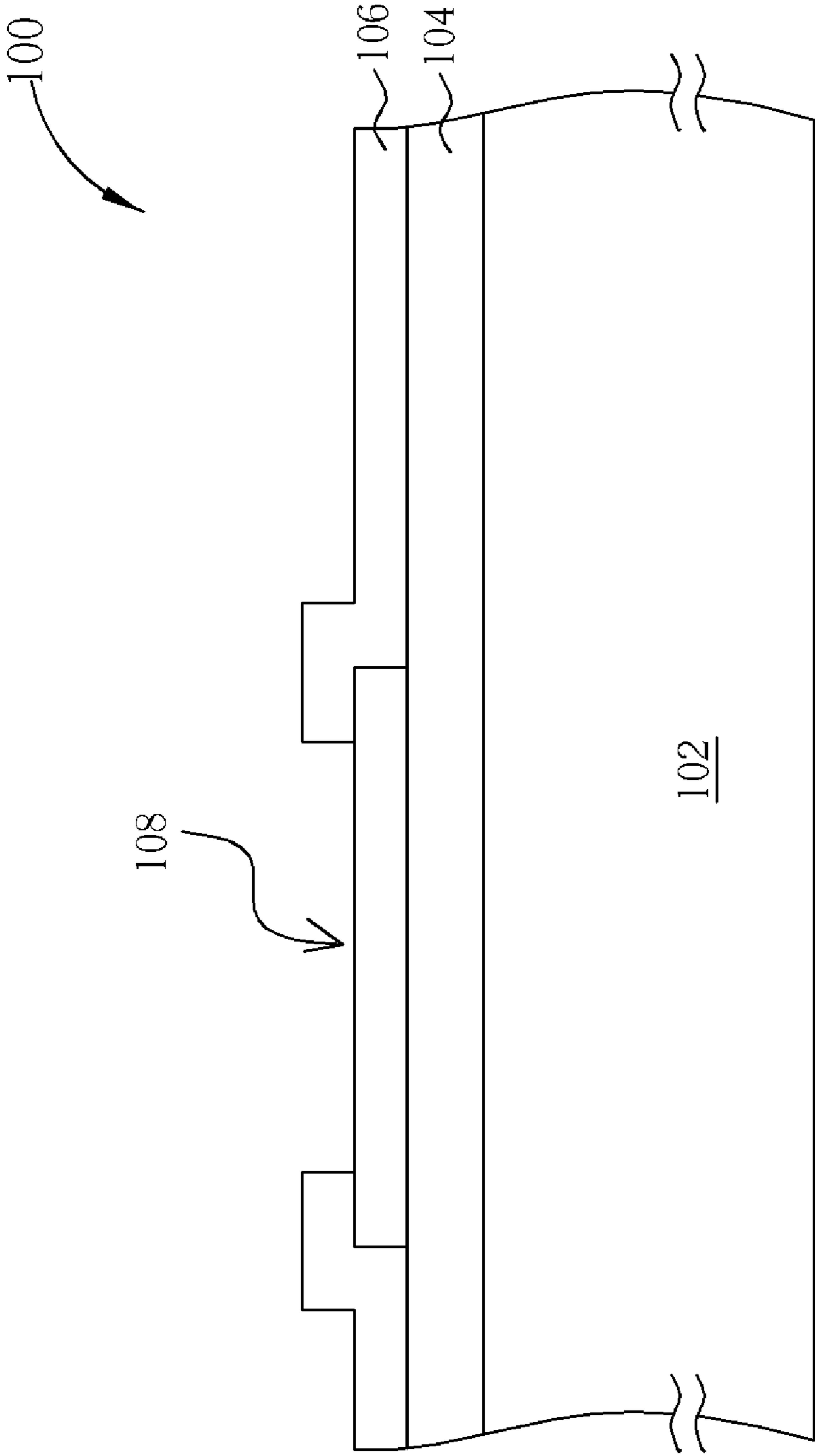


Fig. 1 Prior Art

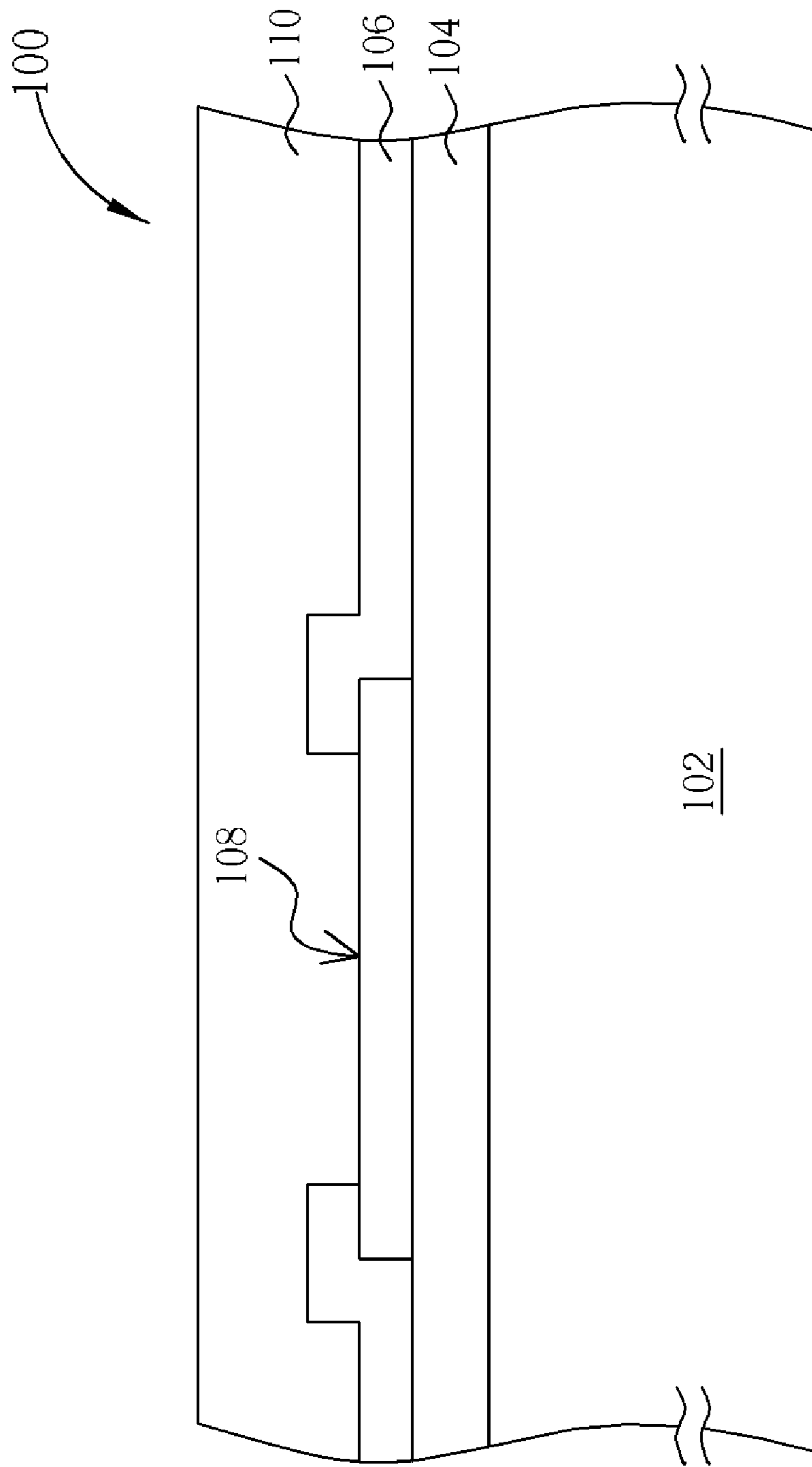


Fig. 2 Prior Art

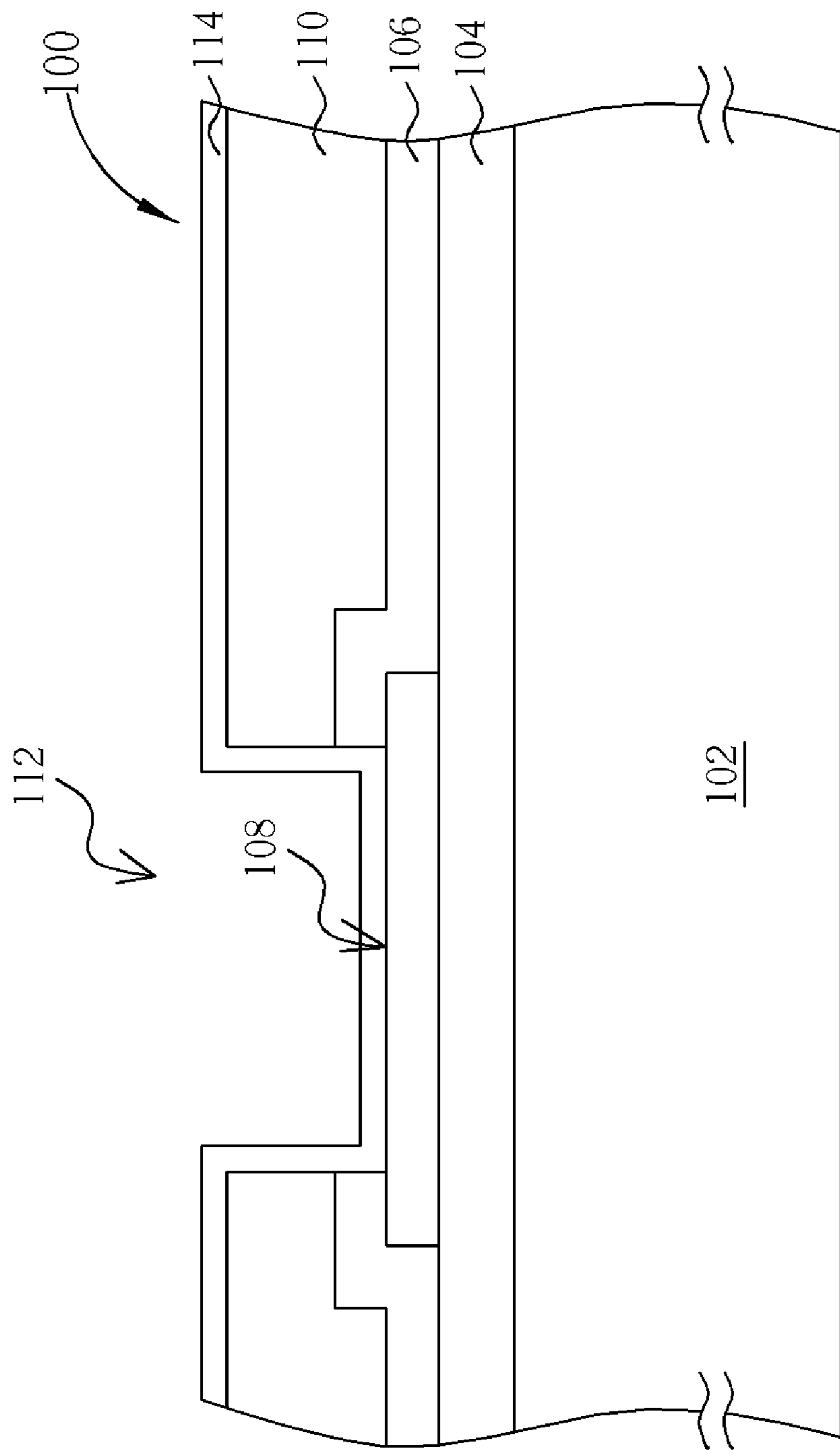


Fig. 3 Prior Art

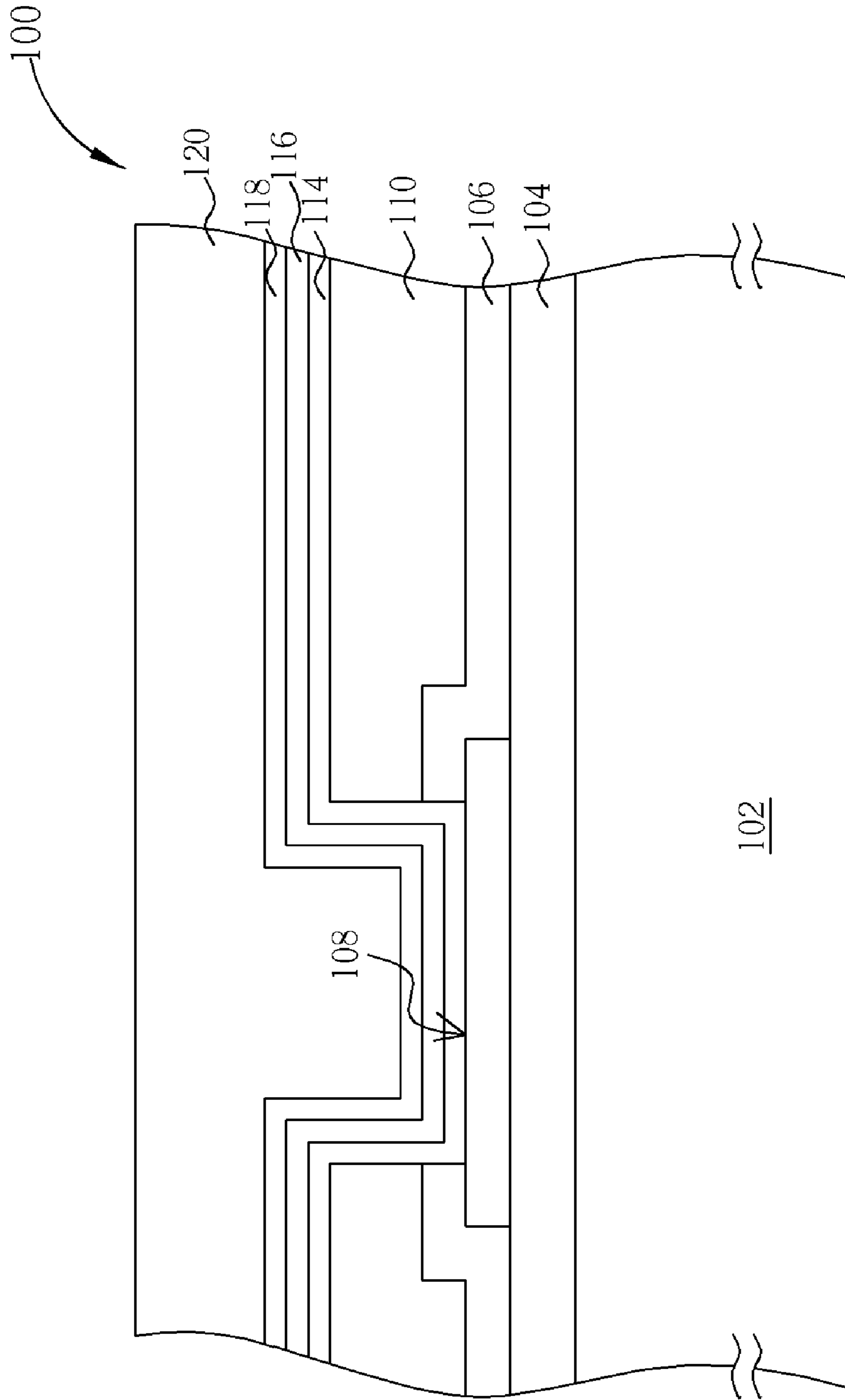


Fig. 4 Prior Art

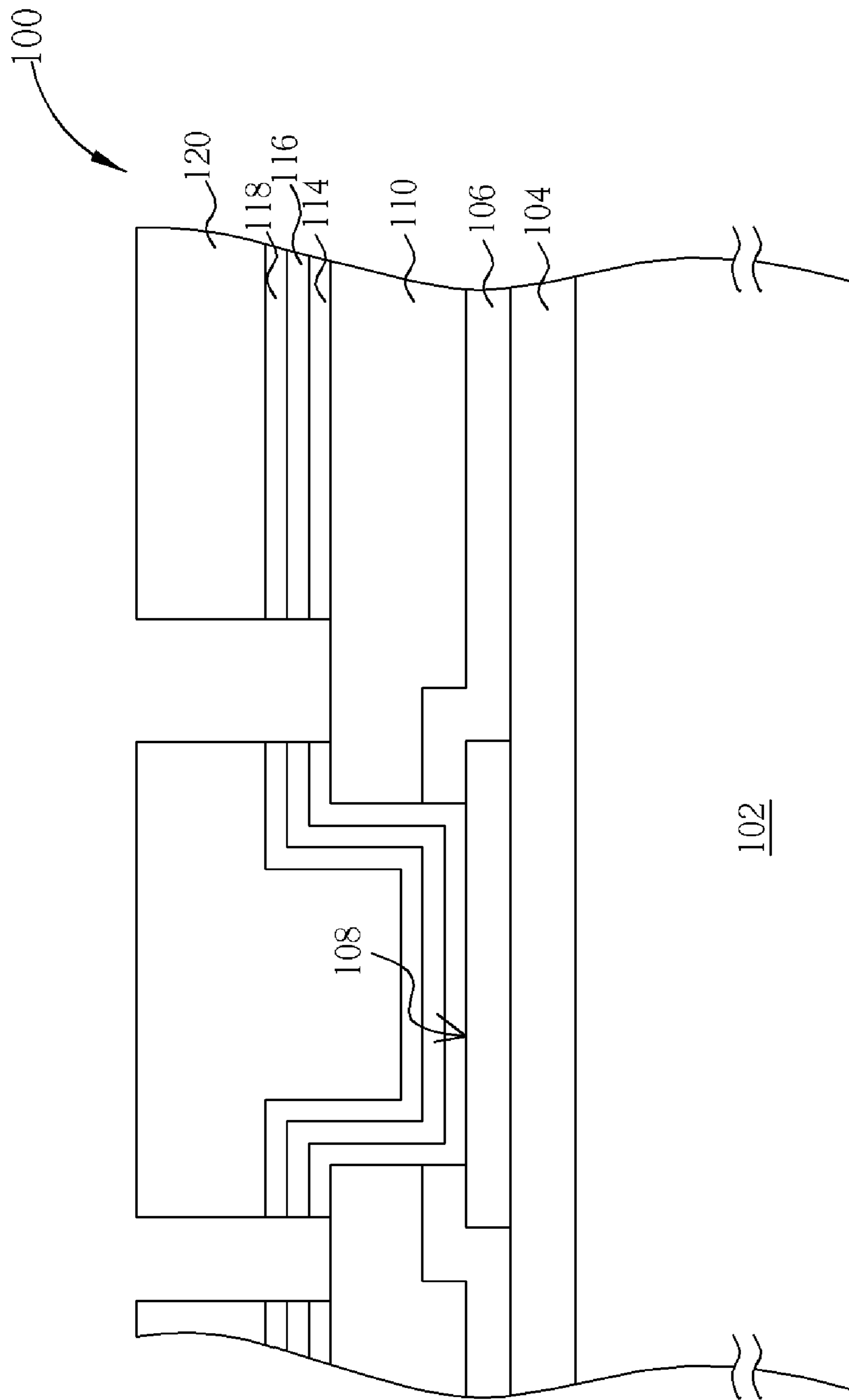


Fig. 5 Prior Art

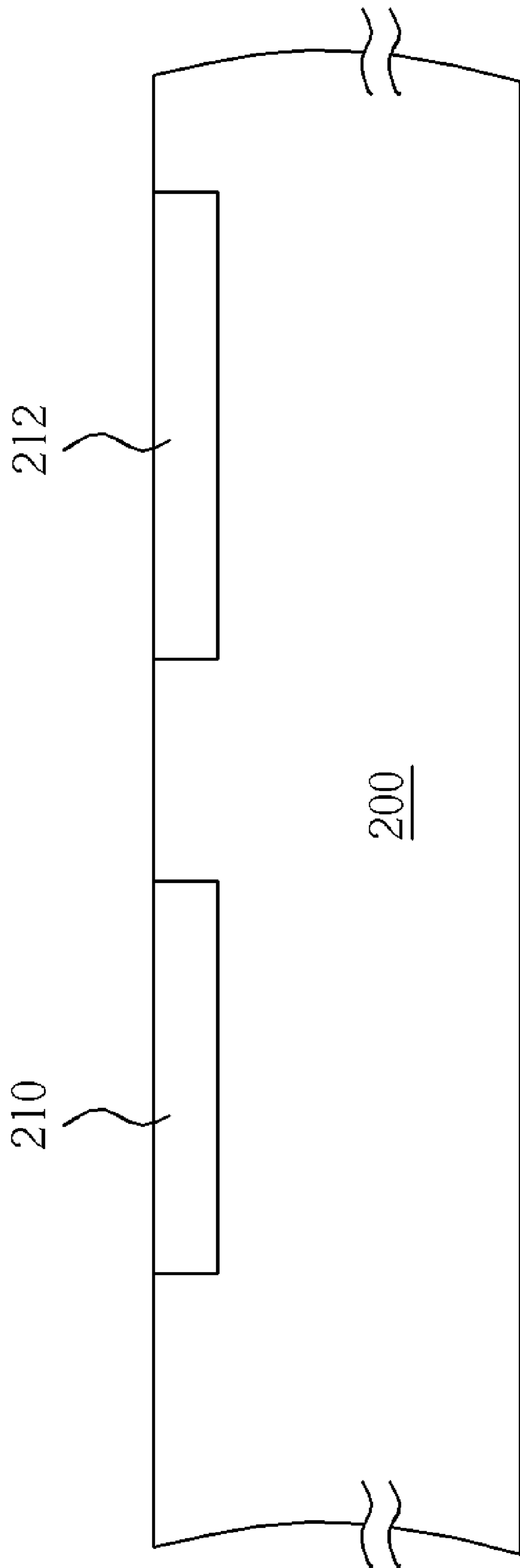


Fig. 6

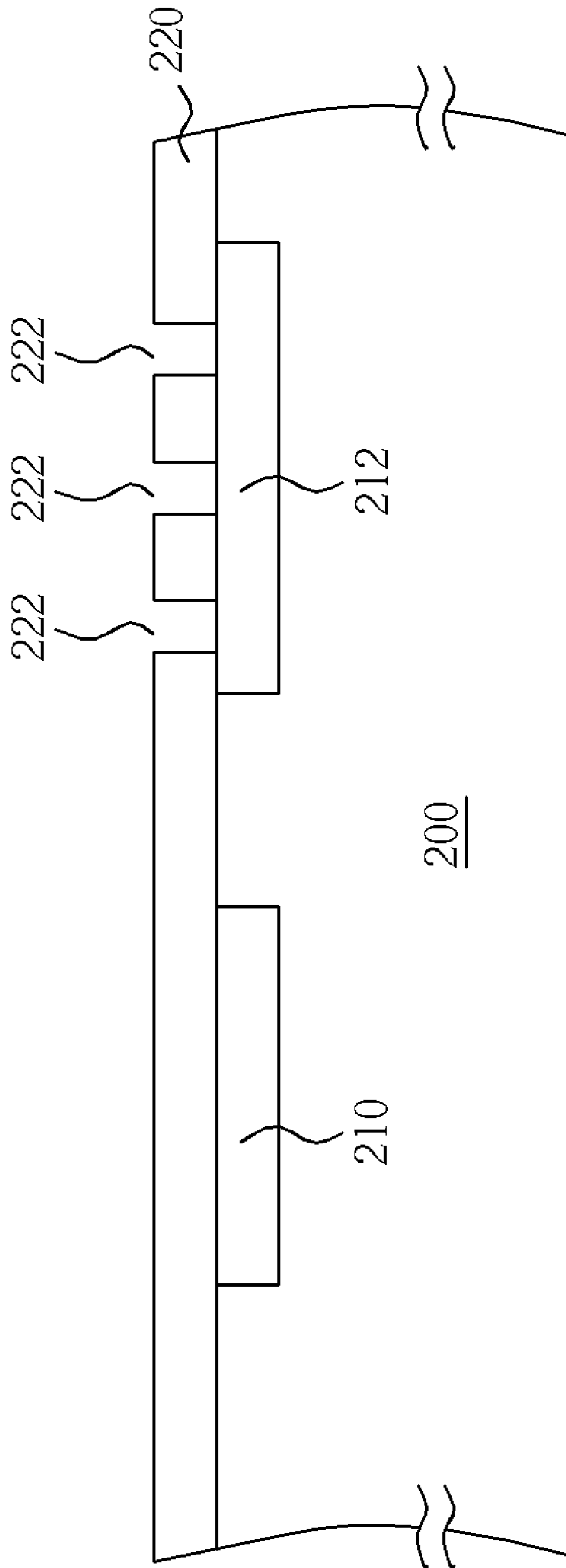


Fig. 7



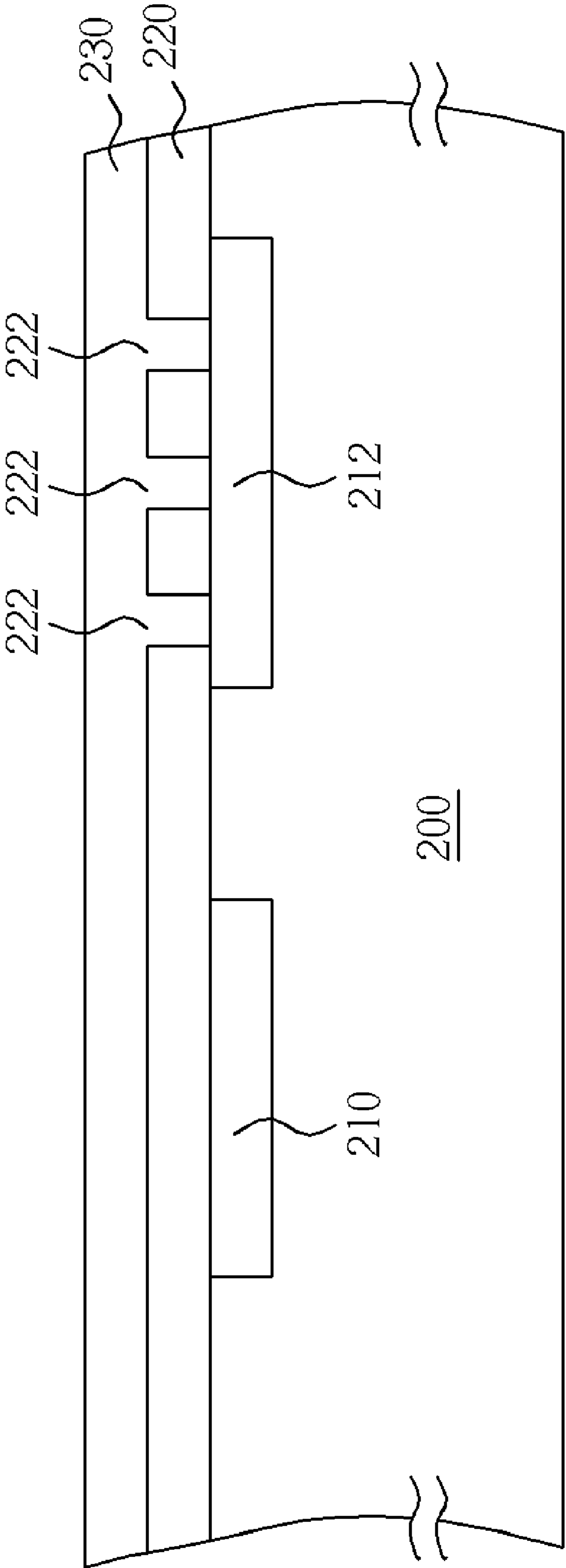


Fig. 8

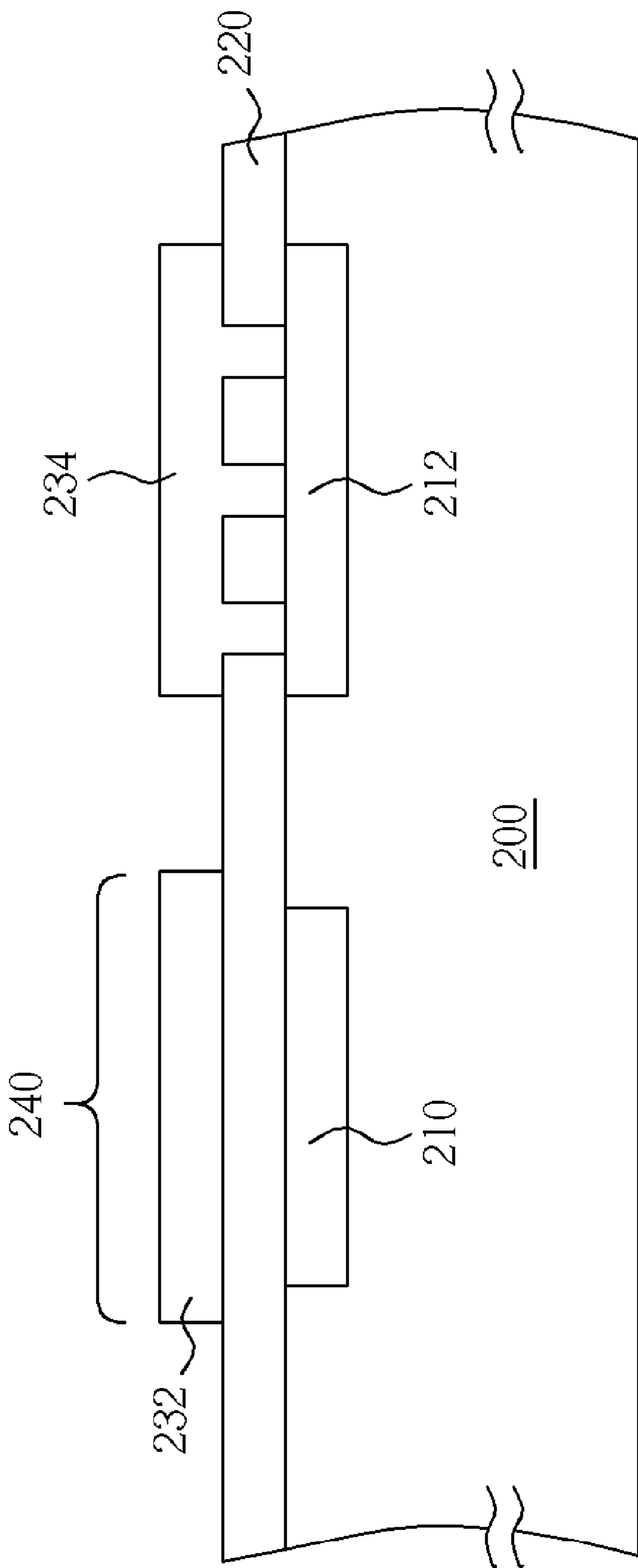


Fig. 9

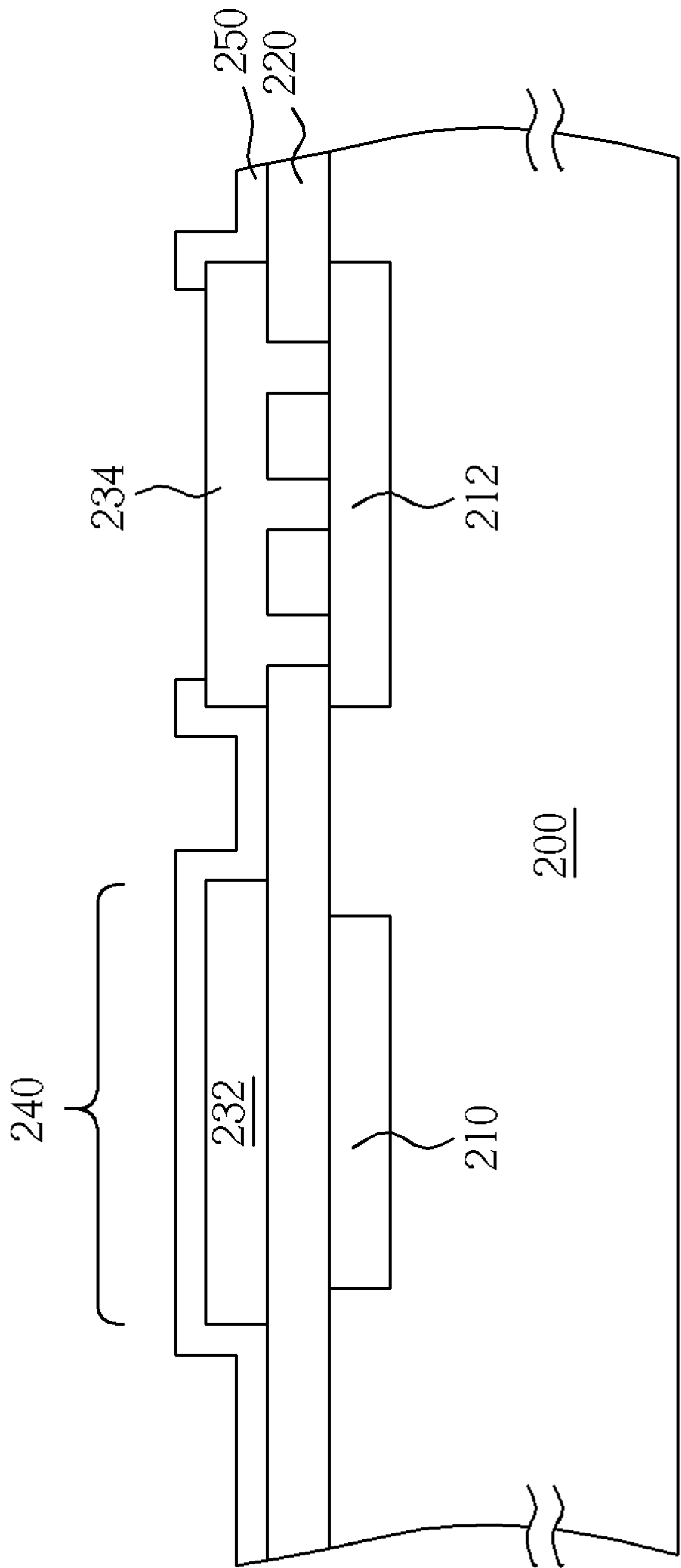


Fig. 10

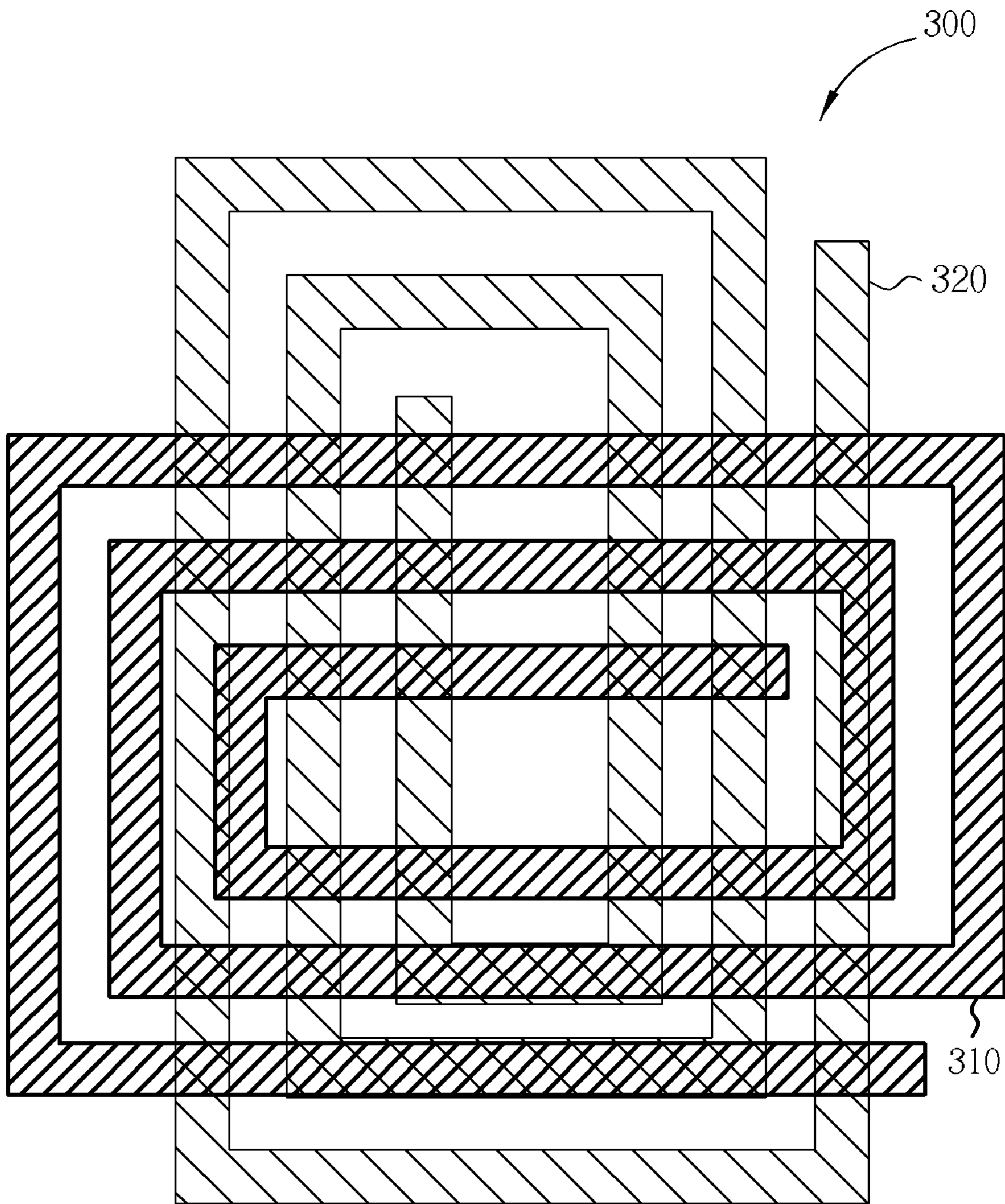


Fig. 11

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## METHOD FOR FABRICATING A TRANSFORMER INTEGRATED WITH A SEMICONDUCTOR STRUCTURE

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to a method for fabricating a transformer integrated with a semiconductor structure, and more particularly, to a method utilizing copper interconnection technology for fabricating a transformer.

#### 2. Description of the Prior Art

It is known in the art that there is an ever-present demand for decreasing the sizes and geometries of electronic components. The demand for decreasing the size of consumer communication and information processing devices has resulted in a general trend in the market to integrate electronic components such as inductors and transformers on a chip.

Please refer to FIGS. 1-5 which are schematic drawings illustrating a method for fabricating a transformer provided by U.S. Pat. No. 6,727,138. In general, the transformer integrated in the semiconductor structure is fabricated in the back-end-of-the-line (BEOL). For example, the transformer is fabricated after completing the fabrication of the contact pads. As shown in FIG. 1, an integrated circuit structure **100** comprises a substrate **102**, a top interconnection metal layer **104** formed by the copper interconnection technology, a protection layer **106**, and a metal pad **108** formed on the top interconnection metal layer **104**.

Please refer to FIGS. 2 and 3. A dielectric layer **110** is formed on the substrate **102**. Then a via **112** corresponding to the metal pad **108** is sequentially formed by the photo-etching process (PEP) on the dielectric layer **110** and exposes the metal pad **108**. And a copper-diffusion barrier layer **114** is formed on the bottom and the sides of the dielectric layer **110** and the via **112**.

Thereafter, as shown in FIGS. 4 and 5, a primary winding layer **116**, a passivation layer **118**, and a secondary winding layer **120** filling the via **112** are successively formed on the copper-diffusion barrier layer **114**, and then a transformer having a coil pattern and electrically connected to the metal pad **108** is obtained.

As abovementioned, the conventional method for fabricating a transformer integrated with a semiconductor structure is performed in back-end-of-the-line (BEOL), especially after completing the fabrication of the metal pad. Therefore the processes are not only complicated, but also increase the cost of manufacturing. Furthermore, as shown in FIG. 5, because the primary winding layer **116** and the secondary winding layer **120** are exposed to the environment, these metal layers are apt to be effected by the moisture and the particles outside, resulting in a poor electrical performance. To solve this problem, there are two main methods in the art: forming a protection layer to entirely cover the primary winding layer and the secondary winding layer after completing the fabrication of the transformer with another PEP performed to expose the metal pad; or encapsulating the chip bearing the transformer by a common mold compound.

### SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a method for fabricating a transformer integrated with a semiconductor structure to solve the problem of the

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transformer fabricating process and the other semiconductor fabricating processes being performed separately and to simplify the processes.

According to the claimed invention, a method for fabricating a transformer integrated with a semiconductor structure is provided. The method comprises providing a substrate, simultaneously forming a top interconnection metal layer and a primary winding layer on the substrate, forming a passivation layer covering the top interconnection metal layer and the primary winding layer on the substrate, the passivation layer further having a plurality of openings exposing parts of the top interconnection metal layer, and simultaneously forming a secondary winding layer and at least a bonding pad on the passivation layer, the bonding pad being electrically connected to the top interconnection metal layer through the openings.

According to the claimed invention, a transformer integrated with a semiconductor structure is further provided. The transformer comprises a substrate, a primary winding layer and a top interconnection metal layer formed on the substrate, a passivation layer formed on the primary winding layer and the top interconnection metal layer, the passivation layer having a plurality of openings exposing parts of the top interconnection metal layer, and a secondary winding layer and at least a bonding pad respectively formed on the passivation layer and the top interconnection metal layer, the bonding pad being electrically connected to the top interconnection metal layer through the openings. The primary winding layer and the secondary winding layer construct the transformer.

According to the method provided by the present invention, a transformer integrated with a semiconductor structure is obtained by simultaneously forming the primary winding layer of the transformer and the top interconnection layer and simultaneously forming the secondary winding layer and the bonding pad. Therefore the purpose to simplify the fabricating processes is achieved.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1-5 are schematic drawings illustrating a method for fabricating a transformer provided by U.S. Pat. No. 6,727,138.

FIGS. 6-10 are schematic drawings illustrating the preferred embodiment according to the method provided by the present invention.

FIG. 11, is a schematic drawing illustrating the transformer according to the preferred embodiment provided by the present invention.

### DETAILED DESCRIPTION

Please refer to FIGS. 6-10 which are schematic drawings illustrating the preferred embodiment according to the method for fabricating the transformer integrated with a semiconductor structure provided by the present invention. As shown in FIG. 6, a substrate **200** such as a semiconductor wafer or a SOI substrate is provided. The substrate **200** comprises an active circuit (not shown) and at least an interconnect metal layer (not shown). Then the substrate **200** is processed using copper interconnection technology to

simultaneously form a primary winding layer **210** of a transformer and a top interconnection metal layer **212** thereon.

Please refer to FIG. 7. A passivation layer **220** having a thickness in a range of 100-500 angstroms is formed on the substrate **200**. The passivation layer **220** covers the primary winding layer **210** and the top interconnection metal layer **212**. Nevertheless, the passivation layer **220** has a plurality of openings **222** used to expose parts of the top interconnection metal layer **212**.

Please refer to FIGS. 8 and 9. Then a metal layer **230** filling the openings **222** is formed on the substrate **200**. The metal layer **230** comprises titanium, titanium oxide, aluminum, or the alloys of the aforementioned metals. A photo-etching process is next performed on the metal layer **230** to simultaneously form a secondary winding layer **232** above the primary winding layer **210** and a bonding pad **234** above the top interconnection metal layer **212**. The primary winding layer **210** and the secondary winding layer **232** construct the transformer **240** provided by the present invention. In addition, because the primary winding layer **210** and the top interconnection metal layer **212** are simultaneously formed on the substrate **200** by the same process and the secondary winding layer **232** and the bonding pad **234** are simultaneously formed on the passivation layer **220** by the same process, the primary winding layer **210** and the top interconnection metal layer **212** are approximately integrated in the same horizontal level while the secondary winding layer **232** and the bonding pad **234** are approximately integrated in the same horizontal level.

It is noteworthy that the bonding pad **234** is electrically connected to the top interconnection layer **212** through the metal layer **230** in the openings **222**. In addition, to reduce the resistance of the transformer **240** and improve the quality factor, the width of the secondary winding layer is larger than the width of the primary winding layer **210**.

Please refer to FIG. 10. Finally a protection layer **250** covering the secondary winding layer **232** and the passivation layer **220** is formed on the substrate **200**. The protection layer **250** exposes the bonding pad **234** for the electrical connection. The fabrication of the bonding pad **234** is completed at this step. The protection layer **250** comprises insulating material such as silicon nitride which can effectively separate moisture. In other words, at the same time when the fabrication of the bonding pad **234** is completed, the secondary winding layer **232** is entirely covered by the protection layer **250** and is unexposed. Therefore the secondary winding layer **232** provided by the present invention is prevented from being affected by the particles and the moisture.

Please refer to FIG. 11, which is a schematic drawing illustrating the transformer integrated with a semiconductor structure provided by the present invention. For convenience, FIG. 11 only shows the primary winding layer and the secondary winding layer of the transformer with other parts omitted. As shown in FIG. 11, a primary winding layer **310** of a transformer **300** is simultaneously formed with a top interconnection metal layer (not shown) in the substrate by the copper interconnection technology; and the secondary winding layer **320** is simultaneously formed with at least a bonding pad (not shown) on the substrate. The transformer **300** further comprises a passivation layer (not shown) formed in between the primary winding layer **310** and the secondary winding layer **320**.

It is noteworthy that the primary winding layer **310** and the secondary winding layer **320** respectively comprise a coil pattern. When a current passes through coil pattern of

the primary winding layer **310**, an inductive current is induced in the secondary winding layer **320** by magnetic induction. In other words, as long as the magnetic lines generated in the electrified coil pattern of the primary winding layer **310** also get across the coil pattern of the secondary winding layer **320**, an inductive current is induced in the secondary winding layer **320**. Therefore the coil patterns of the primary winding layer **310** and the secondary winding layer **320** can be entirely overlapping or, as the layout shows in the preferred embodiment, be partially overlapping. The coil patterns of the primary winding layer **310** and the secondary winding layer **320** can also be coaxial, preferably. In addition, to further reduce the resistance and the improve the quality factor, the width the primary winding layer **310** is smaller than the width of the secondary winding layer **320**. However, the number of coils and the overlapping type is not limited as shown in FIG. 11.

As abovementioned, according to the method for fabricating a transformer integrated in semiconductor structure provided by the present invention, the primary winding layer of the transformer is simultaneously formed with the top interconnection metal layer and the secondary winding layer is simultaneously formed with the bonding pad resulting in a simplified processes and reduced cost. Moreover, the transformer integrated in semiconductor structure provided by the present invention has an advantage of a secondary winding layer protected from moisture by a protection layer formed in the fabrication of the bonding pad. Therefore the transformer provided by the present invention has a high reliability.

Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

1. A method for fabricating a transformer integrated with a semiconductor structure comprising:
  - providing a substrate;
  - simultaneously forming a top interconnection metal layer and a primary winding layer comprising a coil pattern on the substrate;
  - providing a space in between the top interconnection metal layer and the primary winding layer;
  - forming a passivation layer covering the top interconnection metal layer and the primary winding layer on the substrate, and the passivation layer further having a plurality of openings exposing parts of the top interconnection metal layer; and
  - simultaneously forming a secondary winding layer comprising a coil pattern and at least a bonding pad on the passivation layer, and the bonding pad being electrically connected to the top interconnection metal layer through the openings.
2. The method of claim 1, wherein the substrate further comprises an active circuit and at least an interconnection metal layer.
3. The method of claim 1, wherein the passivation layer has a thickness in a range of 100-500 angstroms.
4. The method of claim 1, wherein the top interconnection metal layer and the primary winding layer are simultaneously formed by the copper interconnection technology.
5. The method of claim 1, wherein the secondary winding layer comprises titanium, titanium oxide, aluminum, or alloys of the aforementioned metals.

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6. The method of claim 1, wherein the coil patterns of the primary winding layer and the secondary winding layer are partially overlapping.

7. The method of claim 6, wherein the patterns of the primary winding layer and the secondary winding layer are preferably coaxial. 5

8. The method of claim 1, wherein a width of the primary winding layer is smaller than a width of the secondary winding layer.

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9. The method of claim 1 further comprising a step of forming a protection layer on the substrate, the protection layer covering the secondary winding layer and exposing the bonding pad.

10. The method of claim 9, wherein the protection layer comprises silicon nitride.

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